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Performance Evaluation of PAPR Reduction in OFDM based on Signal Distortion and Signal Scrambling Techniques

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Abstract: ***OFDM is a bandwidth efficient multicarrier modulation has gained a tremendous focus in recent years because of its high spectral efficiency;, multipath delay spread tolerance, effectiveness against impulse noise and frequency diversity. However, some challenging issues still remain unsolved in the design of the OFDM systems. One of the major problems is high Peak-to-Average Power Ratio (PAPR) of transmitted OFDM signals. A large PAPR brings disadvantages like increased complexity to the analog-to-digital (A/D) and digital-to-analog (D/A) converters and a reduced efficiency to the RF power amplifier. In this paper, the proposed techniques are based on Modified selected level mapping and a Hybrid technique used to reduce Peak to Average Ratio of transmitted OFDM signal. And using Matlab simulation result, the proposed techniques are analyzed.***

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Peak to Average Power Ratio (PAPR), Selected Level Mapping (SLM)

1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM), which is one of multicarrier modulation technique, is an attractive technology in wireless communication. As a result, OFDM has been chosen for high data rate communication and has been widely deployed in many wireless communication standards such as Digital Video Broadcasting (DVB) and based mobile worldwide interoperability for microwave access based on OFDM access technology [1].

Recently, some researchers have reported on determinations of the PAPR distribution based on different techniques. T hey are based on Selected mapping algorithm of space frequency coded systems without side information[2], Amplitude limiting and coding[3], Complementary Clipping Transform Technique[4], Clipping with Adaptive Symbol Selection [5], Clipping on Phase on Demand[6], Modified SLM of coded OFDM [7], Standard arrays of Linear Block Codes [8], using Prescrambling method[9], Tone Reservation (TR) and Tone Injection (TI)[10], [11] and Partial Transmit Sequence (PTS).[12] [13][14].

In OFDM, a block of N symbols, {Xn, n=0, 1 ….N-1}, is formed with each symbol modulation, one of a set of N subcarriers {fn, n= 0, 1 …N-1}. The N subcarriers are chosen to be orthogonal, that is, fn= nΔf. Where Δf =1/NT and T is the original symbol period. [2]The resulting signal after D/A conversion can be expressed as

$$x(t)=\sum_{n=0}^{N-1} X_n,\ 0\le t\le NT[15] \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

These time domain samples in the equivalent complex valued low pass domain are approximately Gaussian distributed because of the statistical independence of carriers. The resulting high PAPR is given by

$$PAPR=\frac{\max |x(t)|^2}{E|x(t)|^2}[15]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

If the number of subcarriers is large enough, magnitudes of real and imaginary part of output signal s (t) have Gaussian distribution, and the amplitude of the OFDM signal follows Rayleigh distribution. Power distribution of OFDM symbol is central chi-square distribution with 2 degree of freedom and a mean of zero. The probability density function (PDF) of power is

$$F(z)=1-e-z[15]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Where z is special threshold. Assume that sampled values of PDF in maximum power per OFDM symbol are uncorrelated. In the case of non-oversampling, CCDF, the probability that PAPR is smaller than threshold is

$$CCDF=P(PAPR\le z)=F(z)^N=(1-e^{-z})^N[15] \ldots\ldots (4)$$

The PAPR has the worst case value PAPRWC which depends on the number of subscribers N. The non-linear effects on the transmitted OFDM symbols are spectral spreading, inter-modulation and changing the signal constellation. In other words, the nonlinear distortion causes both in-band and out-of-band interference to signals. The in-band interference increases the Bit Error Rate (BER) of the received signal, while out-of-band interference causes adjacent channel interference through spectral spreading.

2. Proposed PAPR Reduction Techniques

In this section, the Proposed PAPR reduction techniques are analyzed. There are two techniques are discussed. They are Proposed PAPR reduction Technique 1 using Modified Selected Level Mapping.

1. Proposed Hybrid PAPR reduction Technique
2. Using Selected Level Mapping and Clipping.

2.1 Proposed PAPR Reduction Technique1 using Modified Selected Level Mapping

In this technique, the phase set values are changed from [1, -1, j, -j] to [1, -1, j, -j, 1, -1]. In Modified selected mapping method, firstly M statistically independent sequences which represent the same information are generated, and next, the resulting M statistically independent data blocks Sm = [Sm, 0, Sm, 1 , …, Sm, N-1]T, m = 1, 2, …, M are then forwarded into IFFT operation simultaneously. Finally, at the receiving end, OFDM symbols xM = [x1, x2…, xN]T in discrete time-domain are acquired, and then the PAPR of these M vectors are calculated separately. Eventually, the sequences xd with the smallest PAPR will be elected for final serial transmission. Figure. 1 illustrates the basic structure of Modified selected mapping method for suppressing high PAPR for large number of subcarriers.

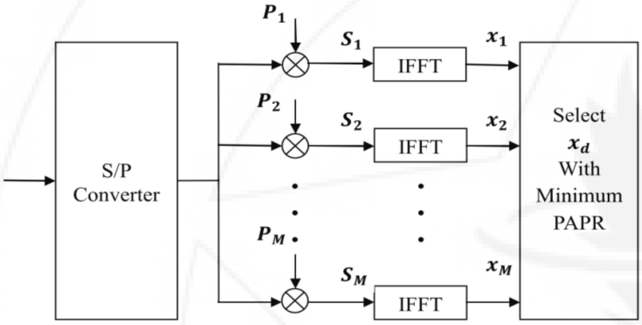

Figure 1: Basic principles of Modified selected mapping technique Phase set 1, -1, j, -j, 1, -1

2.2 Proposed Hybrid PAPR Reduction Technique2 using selected Level Mapping and Clipping

This technique is a combination of selected level Mapping and Clipping. The main idea for combining the two methods is relying on the observation that the cumulative signal processing for PAPR reduction significantly improves the overall performance. Furthermore, the hybrid technique exploits the fact that each of the component methods is based on a different principle.

One performs linear transformation by rotating the vectors from the frequency domain signal, and the other one performs a nonlinear transformation represented by signal limitation. Figure. 2 shows the block diagram of Proposed Hybrid PAPR Technique 2 using Selected Level Mapping and Clipping.

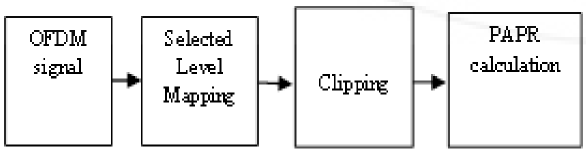

Figure 2: Block diagram of Proposed Hybrid technique 2 using SLM & Clipping

In SLM technique, different representations of OFDM are generated by rotation of the original OFDM frame by different phase sequences and the signal with minimum PAPR is selected and transmitted. Next the signal is applied to clipping technique.

3. Simulation Result

3.1 Selected Level Mapping Technique

In this part, an evaluation of factors which could influence the PAPR reduction performance is performed using MATLAB simulation. Based on the principles of SLM algorithm, it is apparently that the ability of PAPR reduction using SLM is affected by the route number M and subcarrier number N. Therefore, simulation with different values of M and N will be conducted, and the results exhibits some desired properties of signals representing the same information. The rotation factor is defined as Pm, n= [±1, ± j]. This reduces calculation complexity dramatically compared to performing miscellaneous complex multiplication. The algorithm executes 1000 times, over-sampling factor is 8 and QPSK mapping is adopted as modulation scheme in each sub-carrier. Route numbers M=2, M=4, M=8, M=16, M=32and M=64 are used.

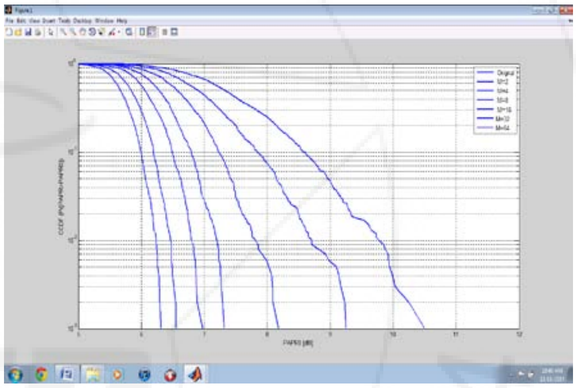

Figure 3: Comparison of PAPR reduction performance for N=64 using SLM

Table 1: PAPR for M values when N=64

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	5.0041	10.7019
2	PAPR2 (M=2)	5.0359	9.6102
3	PAPR3 (M=4)	4.9365	8.6573
4	PAPR4 (M=8)	4.8413	7.3611
5	PAPR5 (M=16)	4.8528	6.9768
6	PAPR6 (M=32)	4.7631	6.5626
7	PAPR7 (M=64)	4.8423	6.3483

From the above results, (Figure.3) it is observed that the maximum value of PAPR when M=1 is 10.7019dB.When M=2, the PAPR value is reduced to 9.6102dB. i.e., PAPR reduction is around 1dB. When M=8, PAPR reduction is 3.3408dB.The PAPR reduction value is around 0.5dB when M is above 8.Table 1 gives PAPR for M values when N=64.

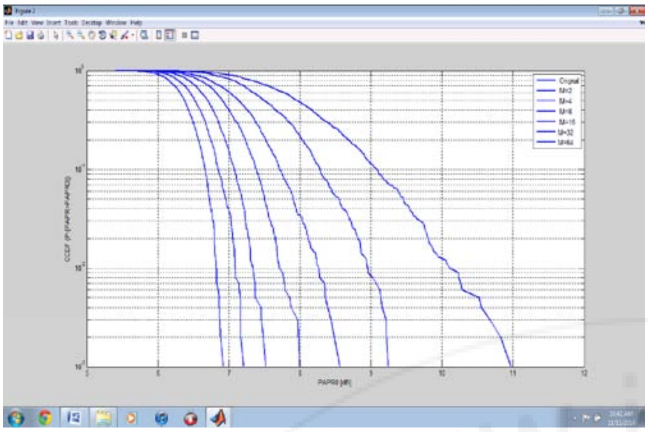

Figure 4: Comparison of PAPR reduction performance for N=128 using SLM

Table 2: PAPR for M values when N=128

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	5.7352	11.1742
2	PAPR2 (M=2)	5.9941	9.3076
3	PAPR3 (M=4)	5.6858	8.7691
4	PAPR4 (M=8)	5.8923	8.1557
5	PAPR5 (M=16)	5.6146	7.6549
6	PAPR6 (M=32)	5.6596	7.4858
7	PAPR7 (M=64)	5.3982	6.9338

From the above results, (Figure 4) it is observed that the maximum value of PAPR when M=1 is 11.1742dB.When M=2, the PAPR value is reduced to 9.3076dB. i.e., PAPR reduction is around 2dB. When M=8, PAPR reduction is 3.0185dB.The PAPR reduction value is around 0.5dB when M is above 8.Table 2 gives PAPR for M values when N=128.

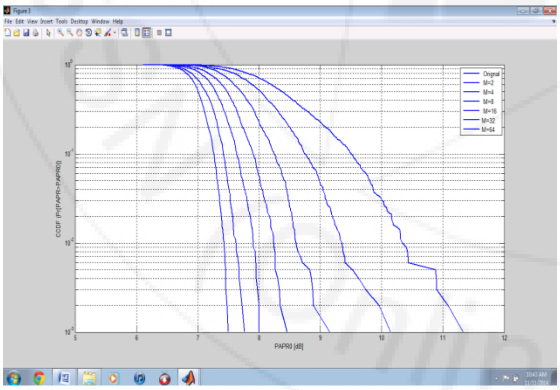

Figure 5: Comparison of PAPR reduction performance for N=256 using SLM

Table 3: PAPR for M values when N=256

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	6.6616	11.6338
2	PAPR2 (M=2)	6.5229	10.1711
3	PAPR3 (M=4)	6.5195	9.2007
4	PAPR4 (M=8)	6.2261	8.4973
5	PAPR5 (M=16)	6.2818	8.0152
6	PAPR6 (M=32)	6.1113	7.7669
7	PAPR7 (M=64)	6.2742	7.6472

From the above results, (Figure 5) it is observed that the maximum value of PAPR when M=1 is 11.6338dB.When M=2, the PAPR value is reduced to 10.1711dB. i.e., PAPR reduction is around 1.5dB. When M=8, PAPR reduction is 3.1365dB.The PAPR reduction value is around 0.5dB when M is above 8. Table3 gives PAPR for M values when N=256.Table 4gives the PAPR values for different subcarriers using SLM technique.

Table 4: PAPR Values for Different Subcarriers Using SLM Technique

S. No.	*N*	*PAPR for Original OFDM (in dB)*	*PAPR for OFDM after SLM (in dB)*	*dB reduction when M=2*
1	64	10.7019	9.6102	1.09
2	128	11.1742	9.3076	1.8666
3	256	11.6338	10.1711	1.4627

Increasing M leads to the improvement of PAPR reduction performance. If the probability is set to 1% and then the CCDF curves with different M values are compared. The PAPR values of case M=2 is around 1dB than the unmodified one M=1. Under the same condition, the PAPR value of case M=16 is about 3dB smaller than the original one M=1. However, from the comparison of the curve M=8 and M=16, the performance difference between these two cases is less than 0.5dB. This proves that to achieve a linear growth of PAPR reduction performance with further increase the value of M (like M>=8), the PAPR reduction performance of OFDM signal will not be considerably improved. Therefore, in practical application, we usually take M=8, thereby not only improve the system performance, but also avoid introducing too much computational complexity so as to save the limited resource successfully.

3.2 Proposed PAPR reduction technique1 using Modified Selected Level Mapping

In this technique, the rotation factor is defined as Pm, n∈ [1, -1, j, -j, 1, -1]. Due to increase of number of subcarriers, PAPR value is reduced more compared to Standard SLM.

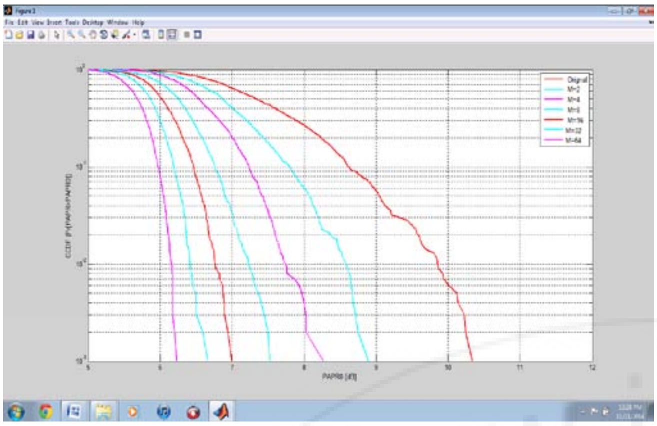

Figure 6: Comparison of PAPR reduction performance for N=64 using Modified SLM

Table 5: PAPR for M values when N=64

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	5.0650	10.6141
2	PAPR2 (M=2)	4.8355	9.5696
3	PAPR3 (M=4)	5.2202	8.3214
4	PAPR4 (M=8)	5.0452	7.6614
5	PAPR5 (M=16)	4.7996	7.1161
6	PAPR6 (M=32)	4.6507	6.6779
7	PAPR7 (M=64)	4.4274	6.3286

From the above results, (Figure 6) it is observed that the maximum value of PAPR when M=1 is 10.6141dB.When M=2, the PAPR value is reduced to 9.5696dB. i.e., PAPR reduction is around 1dB. When M=8, PAPR reduction is 2.9527dB.The PAPR reduction value is around 0.5dB when M is above 8.Table 5 gives PAPR for M values when N=64.

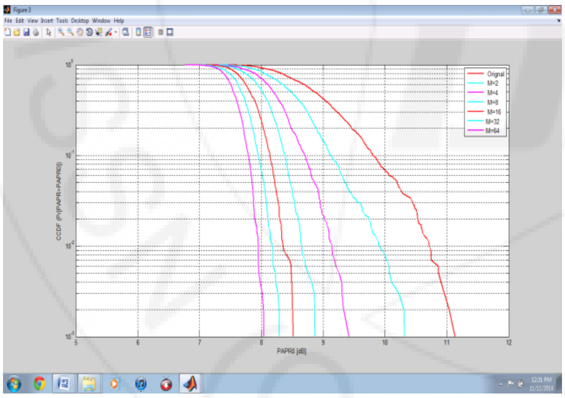

Figure 7: Comparison of PAPR reduction performance for N=128 using Modified SLM

Table 6: PAPR for M values when N=128

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	6.0407	11.8652
2	PAPR2 (M=2)	5.6167	9.7135
3	PAPR3 (M=4)	5.7652	8.8761
4	PAPR4 (M=8)	5.6045	7.8598
5	PAPR5 (M=16)	5.7378	7.5415
6	PAPR6 (M=32)	5.4918	7.3690
7	PAPR7 (M=64)	5.5947	7.0749

From the above results, (Figure.7) it is observed that the maximum value of PAPR when M=1 is 11.8652dB.When M=2, the PAPR value is reduced to 9.7135 dB. i.e., PAPR reduction is around 2.1517 dB. When M=8, PAPR reduction is 4.0054dB.The PAPR reduction value is around 0.3dB when M is above 8.Table 6 gives PAPR for M values when N=128.

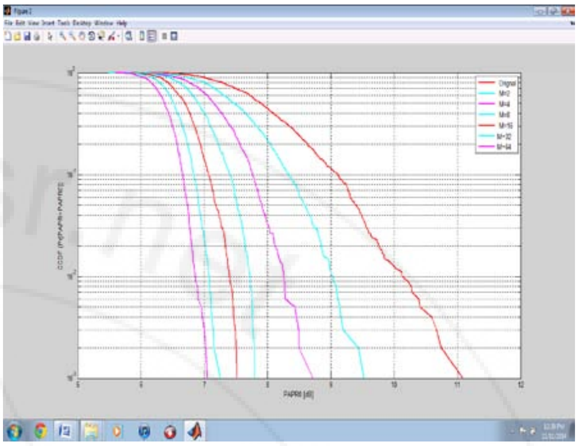

Figure 8: Comparison of PAPR reduction performance for N=256 using Modified SLM.

Table 7: PAPR for M values when N=256

Sr. No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	6.0407	11.8652
2	PAPR2 (M=2)	5.6167	9.7135
3	PAPR3 (M=4)	5.7652	8.8761
4	PAPR4 (M=8)	5.6045	7.8598
5	PAPR5 (M=16)	5.7378	7.5415
6	PAPR6 (M=32)	5.4918	7.3690
7	PAPR7 (M=64)	5.5947	7.0749

From the above results, (Figure 8) it is observed that the maximum value of PAPR when M=1 is 11.6299 dB. When M=2, the PAPR value is reduced to 9.7344 dB. i.e., PAPR reduction is around 2dB. When M=8, PAPR reduction is 3.1067dB.The PAPR reduction value is around 0.3dB when M is above 8.Table 7 gives PAPR for M values when N=256.Table 8gives the PAPR values for different subcarriers using Modified SLM technique.

Table 8: PAPR Values for Different Subcarriers Using Modified SLM Technique

S. No	*N*	*PAPR for Original OFDM (in dB)*	*PAPR for OFDM after Modified SLM (in dB)*	*dB reduction when M=2*
1.	64	10.6141	9.5696	1.0445
2.	128	11.8652	9.7135	2.1517
3.	256	11.6299	9.7344	1.8955

The Simulation results show that the Peak to Average Power ratio is changes due to change of number of subcarriers. The PAPR value is reduced from 10.6141dB to 9.5696dB if the number of subcarriers is64.i.e. the dB reduction is 1.0445. The PAPR value is reduced from 11.8652dB to 9.7135dB if the number of subcarriers is 128. i.e., dB reduction is 2.1517 and for 256 number of subcarriers the dB reduction is 1.8955dB. Therefore, due to increase of number of subcarriers, PAPR value is reduced more compared to Standard SLM. From Figure.6, Figure7, Figure.8, the Modified SLM method displays a better PAPR reduction performance for large number of subcarriers.

3.3 Proposed Hybrid PAPR Technique2 using selected Level Mapping and Clipping

This technique is a combination of selected level Mapping and Clipping. The main idea for combining the two methods is relying on the observation that the cumulative signal processing for PAPR reduction significantly improves the overall performance. Furthermore, the hybrid technique exploits the fact that each of the component methods is based on a different principle.

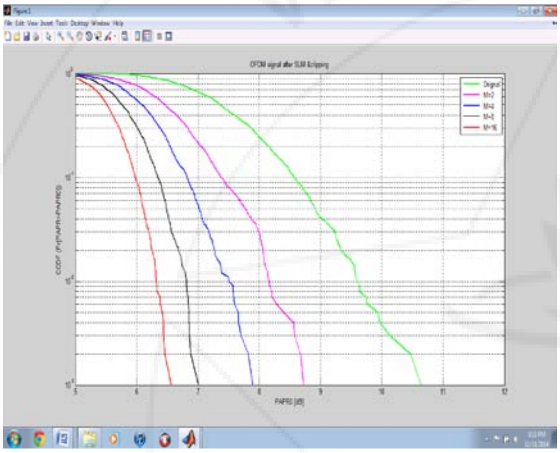

Figure 9: Comparison of PAPR reduction performance for N=64 using SLM & clipping technique.

Table 9: PAPR for M values when N=64

Sr.No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	4.9410	10.9743
2	PAPR2 (M=2)	4.1847	8.9822
3	PAPR3 (M=4)	4.4079	7.9775
4	PAPR4 (M=8)	4.1762	7.0634
5	PAPR5 (M=16)	4.3049	6.8530

From the above results, (Figure 9) it is observed that the maximum value of PAPR when M=1 is 10.9743dB.When M=2, the PAPR value is reduced to 8.9822dB. i.e., PAPR reduction is around 2dB. When M=8, PAPR reduction is3.9109dB.The PAPR reduction value is around 0.2dB when M is above 8.Table 9 gives PAPR for M values when N=64.

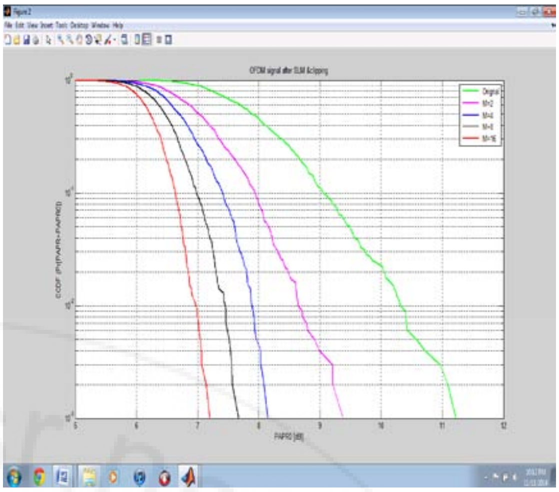

Figure 10: Comparison of PAPR reduction performance for N=128using SLM & clipping technique.

Table 10: PAPR for M values when N=128

Sr.No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	6.0576	11.3349
2	PAPR2 (M=2)	5.2757	9.7081
3	PAPR3 (M=4)	5.3428	8.7056
4	PAPR4 (M=8)	4.9000	7.6704
5	PAPR5 (M=16)	4.8929	7.2978

From the above results, (Figure 10) it is observed that the maximum value of PAPR when M=1 is 11.3349dB.When M=2, the PAPR value is reduced to 9.7081dB. i.e., PAPR reduction is around 1.6268dB. When M=8, PAPR reduction is3.6645 dB. The PAPR reduction value is around 0.3dB when M is above 8.Table 10 gives PAPR for M values when N=128.

Figure 11: Comparison of PAPR reduction performance for N=256 using SLM & clipping technique

Table 11: PAPR for M values when N=256

S.No.	*PAPR*	*Minimum value*	*Maximum value*
1	PAPR1 (M=1)	6.5291	11.3877
2	PAPR2 (M=2)	5.9453	9.9243
3	PAPR3 (M=4)	5.8974	9.1211
4	PAPR4 (M=8)	5.8217	8.2420
5	PAPR5 (M=16)	5.9793	7.8597

From the above results, (Figure.11) it is observed that the maximum value of PAPR when M=1 is 11.3877dB.When M=2, the PAPR value is reduced to 9.9243 dB. i.e., PAPR reduction is around 1.4634 dB . When M=8, PAPR reduction is 3.1457dB.The PAPR reduction value is around 0.3dB when M is above 8.Table 11 gives PAPR for M values when N=256.Table 12 gives the PAPR values for different subcarriers using SLM & Clipping technique.

Table 12: PAPR Values for DIFFERENT Subcarriers Using SLM & Clipping Technique

S.No	*N*	*PAPR for Original OFDM (in dB)*	*PAPR for OFDM after SLM & Clipping (in dB)*	*dB reduction when M=2*
1.	64	10.9743	8.9822	1.9921
2.	128	11.3349	9.7081	1.6268
3.	256	11.3877	9.9243	1.4634

The numerical results have shown that the proposed technique using SLM & Clipping improves the PAPR reduction for N=64 compared with SLM and Modified SLM technique. When the rotation factor is equal to 2 i.e., M=2 gives PAPR reduction is about 2dB which is larger than other two methods. But the numbers of subcarriers are equal to 128 &256, this method gives almost same PAPR performance. Table 12 gives Comparison of PAPR reduction with different techniques.

Table 13: Comparison of PAPR reduction in dB with different techniques

S.No	*N*	*SLM technique*	*Modified SLM technique*	*SLM &Clipping*
1	64	1.09	1.0445	1.9921
2	128	1.8666	2.1517	1.6268
3	256	1.4627	1.8955	1.4634

From Table13, it is observed that if the number of subcarriers N is equal to or less than 64, the SLM & Clipping technique gives larger PAPR reduction performance; if number of subcarriers is equal to and more than 128, the Modified SLM gives better PAPR reduction performance than other techniques.

4. Conclusions

OFDM is a very attractive technique for multicarrier transmission system and has become one of the standard choices for high speed transmission over a communication channel. In this paper, PAPR value is reduced using two techniques like proposed technique 1 using Modified SLM and proposed technique 2 using SLM & Clipping. These proposed techniques are analyzed using Matlab simulation. From the simulation results, it is observed that for number of subcarriers N is equal to or less than 64, the SLM & Clipping technique gives larger PAPR reduction performance and also for number of subcarriers is equal to and more than 128, the Modified SLM technique gives better PAPR reduction performance than other techniques.

Reference

[1] Tao Jiang, Yiyan Wu, “An Overview: PAPR Reduction Technique for OFDM Signal”, IEEE Transaction on Broadcasting, Vol. 54, No. 2, June 2008.

[2] Mahmoud FerdosizadehNaeiny and FarokhMarvasti, Senior Member, IEEE” Selected Mapping Algorithm for PAPR Reduction of Space-Frequency Coded OFDM Systems Without Side Information”, IEEE Transaction on Vehicular Technology, Vol 60, No.3, March 2011.

[3] D. Wulich and L. Goldfeld” Reduction of Peak Factor in Orthogonal Multicarrier Modulation by Amplitude Limiting and Coding”, IEEE Transaction on Communication, Vol 47, No 1 January 1999.

[4] Guangliang Ren, Hui Zhang, and Yilin Chan” A Complementary Clipping Transform Technique for the Reduction of Peak-to-Average Power Ratio of OFDM System. “IEEE Transaction on Consumer Electronics, Vol 49, No.4, November 2003.

[5] Hideki Ochiai, Student Member, IEEE and Hideki Imai, Fellow, IEEE “Performance of the Deliberate Clipping with Adaptive Symbol Selection for Strictly Band limited OFDM Systems”, IEEE Journal on Selected areas in communications, Vol 18, No 11, November 2000.

[6] S. M. Ju and S. H. Leung “Clipping on COFDM with Phase On Demand”, IEEE Communications Letters, Vol 7, No 2, February 2003.

[7] SeungHee Han, Student Member, IEEE, and Jae Hong Lee, Senior Member, IEEE, ” Modified Selected Mapping Technique for PAPR Reduction of Coded OFDM signal”, IEEE Transactions on Broadcasting, Vol 50, No 3, September 2004

[8] Kyeongcheol Yang, Member, IEEE, and Seok-Il Chang “Peak-to-Average Power control in OFDM using Standard arrays of Linear Block Codes” IEEE Communications Letters Vol 7, No 4, April 2003.

[9] KwangDonchoe, Si Chul Kim, S.K. Park, “Pre-Scrambling Method for PAPR Reduction in OFDM Communication System”, IEEE Transaction on Consumer Electronics, Vol. 50, No. 4, Nov 2004.

[10] J.Tellado, “Peak to Average Power Ratio Reduction for Multicarrier Modulation” PhD thesis, University of Standard, Stanford, 1999.

[11] S.S.Yoo, S.Yoon, S.Y.Kim , and I.Song, “ A Novel PAPR reduction scheme for OFDM system: Selective Mapping of Partial Tones (SMOPT), ” IEEE Trans. Consumer Electronics, vol.52, no 1.pp 40-43, Feb.2006.

[12] S.H.Muller and J.B.Huber, “OFDM with reduced peak to average power ratio by optimum combination of partial transmit sequences”, IEE Electronics Letters, vol.33, no 5, pp.36-69, Feb.1997.

[13] S.H.Han and J.H.Lee, “PAPR reduction of OFDM signals using a reduced complexity PTS technique, ” IEEE Signal Processing Letters, vol.11.no 11, pp.887-890, Nov.2004.

[14] A.Alavi, C. Tellambura, andI.Fair, “PAPR reduction of OFDM signals using partial transmit sequence: An optimal approach using sphere decoding,” IEEE Trans. Communication Letters, Vol. 9, no.11, pp.982-984, Nov.2005.

[15] Kwang Don Choe, Member, IEEE, Si Chul Kim, and S.K. Park, Member, IEEE, “Pre-Scrambling Method for PAPR Reduction in OFDM Communication Systems”,

IEEE Trans. On Consumer Electronics Vol 50, No.4, pp 1044-1048 Nov 2004.

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